Weight Effects
Part 2

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In the first part of our discussion of weight effects on performance, we found that both aircraft maximum and cruise velocity were little affected by changes in weight. Each increased approximately one statute mph for each 100 pound reduction in weight below maximum gross weight. We also found that the best glide velocity and the velocity for minimum sink rate decreased as the square root of the ratio of the current weight to the maximum gross weight.

Unfortunately, we found that there is no simple relation for the change in rate-of-climb with weight. Consequently, the results of calculating the change in rate-of-climb were presented in a graph. From the graph we noticed that the percentage increase in rate-of-climb increased with increasing altitude. From the graphical results, can we find a simple conservative rule-of-thumb for *estimating* the increase in rate-of-climb with a reduction in weight? Yes, at sea level the results indicate that the rate-of-climb increases approximately 2% for each 100 pounds below gross weight, while at 8000 feet altitude the increase is approximately 3% for each 100 pounds less than gross weight. However, remember the actual rate-of-climb decreases as the altitude increases. So, you must apply the rule-of-thumb to the actual rate-of-climb at gross weight at the current altitude.

Now let us turn our attention to the effect of weight on the all important stall velocity. First remember that stall velocity is a *derived* quantity, i.e., the actual physical phenomena depends on something else. We just use another quantity to identify the physical phenomena. In this case, we use the velocity to identify the critical angle of attack (technically called the stall angle of attack). Whenever the wing exceeds the critical angle of attack, the wing stalls. The stall velocity is given by

$$V_{\text{stall}} = \sqrt{\frac{2W/S}{\sigma \rho_{\text{SL}} C_{L\max}}} = \text{Constant}\sqrt{W}$$

Thus, the stall velocity *decreases* as the weight *decreases*, i.e.,

$$\frac{V_{\text{stall}}}{V_{\text{stall}}(3300\text{ lbs})} = \sqrt{\frac{W}{W(3300\text{ lbs})}}$$

for a model E33A with a gross weight of 3300 lbs. You can use the graph in Figure 2 on page 19 of the Jan/Feb 1997 (Weight Effects, Part 1) issue to determine the reduction in stall velocity, or simply estimate it using the technique described in the article. That technique is quite simple — take the percentage difference in weight, divide by two and subtract from 100; and multiply the result as a decimal by the stall velocity at gross weight. Here, let's do one. Assume an E33A operating at 3000 lbs. The percentage difference in weight is 300/3300, or about 9%. Dividing by 2 gives 4.5%. Thus, the stall velocity at 3000 lbs is estimated to be 95.5% (100 − 4.5) of that at the gross weight of 3300 lbs. For comparison, the actual square root of the weight ratio is $\sqrt{3000/3300} = 0.953$ or 95.3%, which is close enough. This approximation gives acceptable results for weights as much as 20% less than maximum gross weight.

Now, looking at the formula for the stall velocity we might ask what is this symbol $C_{L\max}$ and what does it have to do with the critical angle of attack and wing stall? $C_{L\max}$ is the maximum lift coefficient of the wing. The maximum lift coefficient occurs at the critical angle of attack. The maximum lift coefficient is usually a number in the range of about 1 to 4. Using the clean power off stall velocity given in the POH for an E33A at maximum gross weight at sea level on a standard day, we can calculate the maximum lift coefficient. The result is 1.37. Now let's go back and look at that equation for stall velocity again. Notice that the maximum lift coefficient occurs in the denominator. If we can *increase* the maximum lift coefficient we can *decrease* the stall velocity. That is exactly what flaps do. Extending the flaps to 30 degrees increases the maximum lift coefficient about 9%. By the way, we talk about the wing stalling. Does the whole wing stall all at once? Actually, it does not. Aeronautical engineers carefully design how a wing stalls. We'll talk more about the lift coefficient and how a wing stalls in subsequent articles.

